

AND PROGRAMS IN HIGH TEMPERATURE CORROSION RESEARCH

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AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92 NEUILLY SUR SEINE FRANCE

AGARD REPORT No. 585

on

**Directory of Organizations,
Investigators, and Programs
in
High Temperature Corrosion Research**

NORTH ATLANTIC TREATY ORGANIZATION



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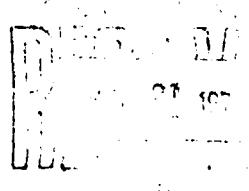
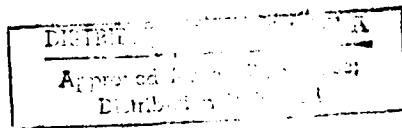
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NORTH ATLANTIC TREATY ORGANIZATION
ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT
(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

DIRECTORY OF ORGANIZATIONS, INVESTIGATORS, AND PROGRAMS
IN HIGH TEMPERATURE CORROSION RESEARCH

Prepared for
The NATO/AGARD Working Group on Basic and Applied
Research and High-Temperature Corrosion



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Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;

Providing scientific and technical advice and assistance to the North Atlantic Military Committee in the field of aerospace research and development;

Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;

Improving the co-operation among member nations in aerospace research and development;

Exchanging of scientific and technical information;

Providing assistance to member nations for the purpose of increasing their scientific and technical potential;

Rendering scientific and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

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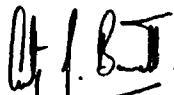
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SUMMARY

This directory of research organizations, investigators, and research programs or areas of research was prepared from information gathered by the NATO/AGARD Working Group on Basic and Applied Research on High-Temperature Corrosion, and the European Federation of Corrosion's Working Group on Corrosion by Hot Gases and Products of Combustion.

The directory lists the organizations, together with the investigators and the research areas (or specific programs) in which they are working, alphabetically by countries. There are 178 organizations from eleven NATO countries included. A category index indicates the high-temperature corrosion research areas in which the various organizations are conducting research. The two research areas currently receiving the most attention are (1) material behavior under corrosion and (2) reaction kinetics and diffusion processes, in which 119 and 97 organizations, respectively, are working. An alphabetical index of investigators includes approximately 240 names.

The AGARD Structures and Materials Panel has an ongoing program of work in this field, organized and coordinated by the Working Group listed on page "v" under the Chairmanship of Mr. T. F. Kearns.


Anthony J. Barrett
Chairman,
Structures and Materials Panel
AGARD

DIRECTORY OF HIGH TEMPERATURE CORROSION RESEARCH

Organizations, Investigations, and Programs

In recent years increased attention has been devoted to the topic of high temperature oxidation and corrosion of structural alloys as a result of increasing operating temperatures being used in the design of aerospace propulsion systems and airframes. The Advisory Group for Aeronautical Research and Development (AGARD) organized under the North Atlantic Treaty (NATO) set up a Working Group on Basic and Applied Research on High Temperature Corrosion Organization of Aerospace Alloys to Study this important topic. At the request of this Working Group, DMIC prepared this directory of the research organizations and principal investigators active in high temperature corrosion and the topics on which they are working. We believe that the directory affords an overview of work in progress and will aid in the assessment of the distribution of the effort and recognition of gaps and objectives not being effectively pursued.

Information on U. S. and Canadian programs in the directory was obtained by DMIC through a direct mail questionnaire sent in 1970 to researchers who were believed to be active in high-temperature corrosion research. Information on European programs was taken from a 1967 survey of European high-temperature corrosion research conducted by the Working Group on "Corrosion by Hot Gases and Products of Combustion" of the European Federation of Corrosion (EFC). The information selected from the EFC survey was limited to NATO countries* and to high-temperature corrosion in the categories listed below.

Category Index

- 1.1 Thermodynamics, phase diagrams, reaction equilibria
- 1.2 Electrochemical problems
- 1.3 Reaction kinetics and diffusion processes
- 1.4 Aerodynamic factors (mechanism of deposition)
- 1.5 Rheological investigations (viscosity of the melts)
- 2.1 Development of corrosion-resistant materials
- 2.2 Surface protection of materials
- 2.3 Material behavior under corrosion
- 3.1 Additives
- 3.4 Surface treatment of pipes, supports, and other parts of furnaces, boilers, turbines, etc., exposed to high temperature

In the interest of uniformity, these category codes were used in Table 2 of this directory. In addition, when more complete information was not available, these categories were used to indicate the areas, in Table 1, in which research was being conducted by the European laboratories.

(*) Spain is not within NATO but some laboratories in this Country known to have interests in High Temperature Corrosion work have been included in this directory by courtesy of the Spanish laboratories concerned.

Members of the NATO/AGARD Working Group on Basic and
Applied Research on High-Temperature Corrosion

T. F. Kearns United States, Chairman
A. Deruyttere Belgium
H. V. Kinsey Canada
J. P. Pouliquenier France
F. Bollenrath Germany
A. Griselli Italy
P. Kofstad Norway
A. d'Oliveira Sampaio Portugal
H. P. van Leeuwen Netherlands
K. A. Rowland United Kingdom
N. Tallan United States
R. I. Jaffee U. S., Specialist
J. Dunham U. K., Liaison, Propulsion
and Energetics Panel,
AGARD

Members of the European Federation of Corrosion
Working Group on Corrosion by Hot Gases
and Combustion Products

H. Souresny Austria
H. Zitter "
M. Caubo Belgium
Prof. Leclerc "
Prof. Pourbaix "
E. Aggernaes Denmark
Z. Bret Czechoslovakia
Prof. Tikkonen Finland
Prof. Bardolle France
Dr. Manenc "
K. Lorenz Germany
W. Möller "
A. Rahmel "
W. Schilder "
Dr. Tuillo Italy
D. Borgese "
J. M. N. Jeijersma Netherlands
Dr. de Jonge "
P. Kofstad Norway
S. Feliu Spain
J. H. González "
L. O. Härdelius Sweden
O. Stelling "
A. Bukowiecki Switzerland
Th. Geiger "
M. Heise "
A. B. Hart United Kingdom
G. Wood "

TABLE I. DIRECTORY OF ORGANIZATIONS,
INVESTIGATORS, AND PROGRAMS

- BELGIUM
1. Belgian Center for Corrosion Study, CEBELCOR
Avenue Paul Héger, Grille 2
B-1050 Bruxelles
M. Fourbaix (02) 49.63.96
A. Pourbaix
G. vanMuyldae
Programs:
1. Preparation of an atlas of chemical and electrochemical equilibria for oxides, hydrides, sulfides, chlorides, hydrates, and other compounds, with special reference to the conditions of stability of protective films
2. Preparation of diagrams of electrochemical equilibria of materials in the presence of molten salts (carbonates, chlorides, fluorides, sulfates) and in the presence of semiconductive oxides
 2. Centre de Recherches Metallurgiques (C.R.M.)
rue du Val Benoît, 69
B-4000, Liege (04) 52.70.50
A. Davin
D. Coutsouradis
L. Habraken
Programs:
1. Dry corrosion of superalloys in sulphidizing and carburizing atmospheres
2. Development of hot corrosion resistant cobalt base alloys
3. Evaluation of coating stability under hot corrosion conditions
 3. Faculté Polytechnique
Département de Chimie
Laboratoire d'Electrochimie
Rue de l'Epargne
Mons
Prof. H. Van der Poorten
Programs:
1. Corrosion of refractory metals by molten silicates
2. Reaction kinetics and diffusion processes
3. Material behavior under corrosion
 4. Institut Belge des Hautes Pressions
Sterrebeek
L. Deffet
P. Westermans
Research Areas:
2.3
 5. Institut de Métallurgie de la Faculté des Sciences Appliquées
de l'Université Catholique de Louvain
de Croÿlaan, 2
3030 Heverlee
Leuven
Claude Vanleughem 016/327.47
Program:
1. Corrosion of inconel 600 alloy in water vapor at high temperature
2. Reactions in the system Ac_2O_3 - ThO_2 -W and La_2O_3 - ThO_2 -W including daughter products Re, Pb, and O. Study of phase diagrams, volatilization, permeability
3. Reactions in the system ThO_2 -W-O-Re-Pb
4. Reactions in the system LaN - AlN -N-W-Ph
5. Steam oxidation of chromium coatings on steel
6. Hot salt cracking of titanium alloys
 6. Katholieke Universiteit Leuven
Department Metaalkunde
3030 Heverlee
Leuven
Dr. M. J. Brabers
Research Areas:
1.1, 1.3, 2.2, 2.3
1. Reactions in the system Ac_2O_3 - ThO_2 -W and La_2O_3 - ThO_2 -W including daughter products He, Pb and O. Study of phase diagrams, volatilization, permeability.
2. Reactions in the system ThO_2 -W-O-He-Pb
3. Reactions in the system LaN - AlN -N-W-Pb
4. Steam oxidation of chromium coatings on steel
5. Hot salt cracking of titanium alloys
 7. Laboratoire Belge de l'Industrie Electrique, LABORELEC
Rhode-Saint-Géry
G. Taelmans
Research Areas:
2.2, 3.4
 8. Laboratoire Central
Rue de la Discipline
6060 Gilly
S. A. Glaverbel (07) 31.01.65
Programs:
1. Reaction of alloys with molten salts (silicates)
2. High temperature coatings development (plasma-spraying and diffusion coatings)
3. Temperature effects on coatings and intermediate layers
 9. SCK/CEN (Centre D'Etude de L'énergie Nucléaire)
Metallurgy Department
2400 Mol
F. Casteels
Programs:
1. Compatibility of W(W-Re) with oxides (PbO , WO_3 , Bi_2O_3 , ThO_2 , La_2O_3 , Ac_2O_3 , BaO , Ba, Pb, Bi) in the temperature range 1500 - 2200 C
- CANADA
10. Atomic Energy of Canada Limited
Chalk River Nuclear Laboratories
Materials Science Branch
Chalk River, Ontario
B. Cox (613) 687-5581 Ext. 563
Programs:
1. Oxidation of zirconium
 11. Ecole Polytechnique
Département de Génie Métallurgique Chimique
Division de Métallurgie
2500 Avenue Marie Guyard
Montreal, 250, Quebec
M. Rigaud (514) 739-2451 Ext. 282 or 241
Programs:
1. Oxidation of nickel, cobalt, niobium, nickel-cobalt, nickel-niobium alloys
2. Initial stages of film formation
3. Spectrophotometric study of products formed during the oxidation of nickel binary alloys Ni-Nb, Ni-Ti, Ni-Al

12. Falconbridge Nickel Mines, Ltd.
 Metallurgical Laboratories
 Process and Products Development Group
 8810 Yonge Street
 P.O. Box 900
 Thornhill, Ontario
 Dr. L. A. Morris
- Programs:
1. Oxidation of austenite stainless steels
 2. Oxidation and hot corrosion of high chromium, nickel-chromium alloys
 3. Sulfidation of high chromium, nickel chromium, alloys
13. McMaster University
 Department of Metallurgy and Materials Science
 Hamilton, Ontario
 Prof. W. W. Smeltzer (416) 522-4971
- Programs:
1. Oxidation properties of zirconium and a zirconium-2.5 w/o niobium alloy
 2. Oxidation-decarburization properties of steels
 3. Thermodynamics of binary alloys and oxygen
 4. Oxidation properties of iron-silicon and nickel-iron alloys
 5. Oxidation properties of nickel
 6. Reactant transport properties in oxide films and scales
 7. Sulfidation properties of nickel-chromium alloys
14. National Research Council of Canada
 Metallic Corrosion and Oxidation Section
 Chemistry Division
 Ottawa 7, Ontario
 Donald Caplan (613) 993-2318
- Programs:
1. Oxidation of Fe, Ni, Cr: kinetics, effect of pressure, purity, surface preparation, cold work, surface contamination with Si, C, S
 2. Electron-optical characterization of metal surfaces: high energy electron diffraction and X-ray emission analysis of surfaces and their reaction products: Fe, Ni, W, Ta, Si
 3. Initial stages of film formation on Fe, Ni, Si, and W single crystals: nucleation, epitaxy, kinetics, ultrahigh vacuum techniques
 4. Grain structure and cavities in oxide layers
 5. Oxidation of Fe-C alloys
 6. Anodically formed oxides on Fe: kinetics, electrochemistry, electron-optical examination, and autoradiography
 7. Contamination of metal surfaces from hot ceramics; gas phase transport mechanism
15. National Research Council of Canada
 National Aeronautical Establishment
 Structures and Materials Laboratory
 Ottawa, Ontario
 J. M. Trenouth (613) 993-2812
 Dr. W. Wallace (613) 993-9280
 Dr. E. P. Whelan (613) 993-2812
- Programs:
1. Preparation and evaluation of vacuum pack Cr-Ti-Si coatings on B66 alloy (nearing completion)
 2. Oxidation of silicide compounds, diffusion coatings, and binary Nb alloys (being initiated)
 3. Corrosion of silicide coatings by Na₂SO₄ and NaCl
 4. Oxidation kinetics and breakdown mechanisms in diffusion coated niobium and niobium-base alloys
5. Oxidation kinetics and structural stability of intermetallic compounds
6. Impurity diffusion of Cr, Ti, Si in niobium
7. Oxidation resistance of commercial aluminide coatings on superalloys 713C and IN-100 (recently completed)
16. Orenda Limited
 Box 6001
 Toronto International Airport
 Toronto, Ontario
 W. Paul (416) 677-3250
- Programs:
1. Evaluation of high-temperature corrosion properties of nickel- and cobalt-base superalloys after long term exposure to straight oxidizing atmospheres
 2. Evaluation of turbine components after long periods of service in Orenda's industrial base turbine engines
 3. Study of the effects of various surface treatments such as shot peening and aluminide coatings
17. Queen's University
 Centre for Metal and Mineral Technology
 Chemical Metallurgy Research Group
 Kingston, Ontario
 John R. Wilson (613) 547-2816
- Programs:
1. High-temperature corrosion of metallic and refractory materials in oil combustion products (including sulfidation and vanadate corrosion)
 2. High-temperature corrosion of molybdenum in aggressive gaseous environments (mainly halogen gases and hydrogen sulfide)
 3. Corrosion of metallic and refractory materials by molten salts and slags (predominantly the refractory metals by molten fluorides, and commercial refractories by molten oxides)
18. Sherritt Gordon Mines, Ltd.
 Research and Development Division
 Fort Saskatchewan, Alberta
 L. F. Norris (403) 543-2211
- Programs:
1. Improvement of the oxidation resistance of dispersion strengthened nickel-chromium alloys (includes static and dynamic oxidation testing, hot corrosion testing from 1800 - 2200 F)
19. University of Western Ontario
 Faculty of Engineering Science
 Materials Science Group
 London, Ontario
 C. Roy
 J. S. Sheasby (519) 679-3302
- Programs:
1. Stress generation during oxidation of zirconium alloys
 2. Effects of growth stresses on oxide morphology for zirconium alloys
 3. High-temperature corrosion resistant coatings for zirconium alloys
 4. Effect of surface orientation of the metal substrate on the oxide film growth
 5. High-temperature oxidation behavior of niobium
 6. Lower oxide formation during oxidation reactions
 7. Electrical properties of oxides during formation on a metal

DENMARK

20. Universität von Kopenhagen, Kemisk Lab. IV
 Copenhagen
 N. F. Grönlund
 Research Areas:
 1.1, 1.2

FRANCE

21. Centre d'Etudes Nucléaires de Saclay
 Service de Chimie des Solides
 Boite Postale N° 6
 92 Fontenay-aux-Roses
 R. Darras
 J. Paidassi
 Research Areas:
 1.3
22. Centre National de la Recherche Scientifique
 15 Rue Georges Urbain
 94 Vitry-sur-Seine
 P. Lehr
 Research Areas:
 1.1, 2.1, 2.2, 2.3
23. Centre de Recherches Métallurgiques de l'Ecole des Mines
 60, Boulevard Saint-Michel
 75 Paris V^e
 P. Lacombe
 G. Beranger
 Research Areas:
 1.2
24. Centre de Recherches de la Société Métallurgique d'Imphy
 Imphy-58
 P. Legendre
 Research Areas:
 2.1, 2.2, 2.3
25. Ecole Centrale des Arts et Manufactures
 Centre Recherche Physique
 1 Rue Mongolfier
 Paris 3^e
 Gregoire
 Research Areas:
 2.3
26. Ecole des Mines
 Laboratoire de Chimie-Métallurgie
 Parc de Saurupt
 54 Nancy
 Roux
 Slama
 Research Areas:
 1.1, 1.3
27. Ecole Nationale Supérieure de Chimie de Paris
 47 Rue des Ecoles
 75 Paris 5^e
 J. Benard (See also #42)
 J. Oudar
 Research Areas:
 1.2, 2.2
28. Ecole Nationale Supérieure Electrochimie et Electrometallurgie
 39-41 Boulevard Gambetta et Rue Hoche
 38 Grenoble
 Besso.
 Research Areas:
 1.2, 1.3

29. Forges et Acieries du Saut du Tarn

6 avenue de Messine
 75-Paris 8eme
 M. Mailhos
 Research Areas:
 2.2

30. Institut de Recherches de la Siderurgie

185 Rue du Président-Roosevelt
 78 St.-Germain-en-Laye
 J. Manenc
 Research Areas:
 1.3, 2.2

31. Laboratoire de Recherche sur la Réactivité des Solides associés au CNRS

21 Rue Monge
 21 Dijon
 P. Barret
 Research Areas:
 1.1, 1.3

32. Office National d'Etudes et de Recherches Aérospatiales-ONERA

29, Avenue de la Division Leclerc
 92 Chatillon-sous-Bagneux
 P. Gaimiche
 A. Hivert
 R. Pichoir
 G. Slodzian
 H. Bückle
 Research Areas:
 1.1, 1.3, 2.1, 2.2

33. Société Nationale d'Etudes et de Construction de Moteurs Aéronautiques-SNECMA, Laboratoire Central-Usine d'Evry-Corbeil

Boite Postale N° 56
 91 Corbeil
 Brunetaud
 Ferre
 Research Areas:
 2.2, 2.3

34. Société Nationale Industrielle Aérospatiale-SNIAS

Laboratoire Central
 Rue de l'Industrie
 92 Courbevoie
 Sertour
 Research Areas:
 2.2

35. Société Ugine-Kuhlmann

Laboratoire de Ventron
 73 Albertville
 J. P. Givord
 Research Areas:
 2.2

36. Trefimetaux G. P.

Département de Recherches Avancées
 141 Rue Michel Carré
 95 Argenteuil
 Syre
 Molinier
 Research Areas:
 2.1

37. Université d'Amiens

College Scientifique
 18 Place St. Michel
 80 Amiens
 F. Marion
 Programs:
 1.1, 1.3

38. Université de Lyon
69 Lyon
Uzan
Research Areas:
1.3
39. Université de Marseille
Laboratoire de Chimie Générale
Lab. de Cristallographie
13 Marseille
M. Lafitte
Dreschler
Research Areas:
1.1, 1.3, 2.3
40. Université de Nancy
Laboratoire de Chimie Minérale
13 Place Carnot
54 Nancy
Vigne
Research Areas:
1.3, 2.2, 2.3
41. Université d'Orléans
Labor de Chimie des Solides
21 Rue Saint-Etienne
45 Orleans-la-Source
J. Bardolle
Research Areas:
1.1, 1.3
42. Université de Paris
Lab. de Chimie
47 Rue des Ecoles
Paris 5^e
J. Benard
J. Oudar (See also #27)
Research Areas:
1.1, 1.3
43. Université de Poitiers
Laboratoire de Chimie
5 Cité de la Traverse
Poitiers
G. Valensi
Research Areas:
1.1, 1.2, 1.3
44. Université de Tours
Laboratoire Chimie Générale et Minerale
1 bis Boulevard Tonnellé
37 Tours
P. Belin
Research Areas:
1.1, 1.3
- GERMANY
45. August Thyssen-Hütte AG
41 Duisburg-Hamborn
Kaiser-Wilhelm-Str. 100
Ch. Strassburger
Research Areas:
2.3
46. Babcock-Werke
Forschung und Entwicklung
42 Oberhausen
Postf. 34/35
H. Jahn
H. Büskens
Research Areas:
2.3
47. Battelle-Institut e.V.
6000 Frankfurt/Main 90
Postschliessfach 900/60
H. Ahlborn
Programs:
1. Oxidation resistance of high-temperature
alloys containing special additions
48. Berliner Kraft- und Licht-AG, BEWAG
1 Berlin 30
Stauffenbergstr. 26
K. Wickert
Research Areas:
1.3, 1.5, 3.1
49. Brown, Boveri & Cie
Zentralstelle für Werkstofftechnik
68 Mannheim 1
Postfach 351
H. Möller
Research Areas:
1.1, 1.3, 2.2, 2.3, 3.1, 3.4
50. Dechema-Institut
6 Frankfurt
Rheingau-Allee 25
Dr. A. Rahmel
Programs:
1. High-temperature oxidation of iron and steels
2. Electrochemical studies of corrosion in al-
kali-sulfate and V₂O₅ melts.
51. Deutsche Edelstahlwerke AG
415 Krefeld
Oberschlesienstr. 16
Dr. K. Bungardt
Dr. G. Lennartz
Research Areas:
1.3, 2.2, 2.3
52. Edelstahlwerk Witten AG
581 Witten
Postfach 1369
J. Bruch
Research Areas:
2.1, 2.3
53. Forschungsvereinigung Verbrennungskraftmaschinen
6 Frankfurt-Niederrad 1
Lyoner Strasse
F. Umland
W. Möller
Research Areas:
1.1, 1.3, 2.1, 2.3, 3.1, 3.4
54. Hamburgische Elektrizitätswerke
2 Hamburg 1
Gerhart-Hauptmann-Platz 48
Pfeiffer
Research Areas:
1.1, 1.2, 1.3, 2.3
55. International Nickel Deutschland GmbH
4 Düsseldorf
Kreuzstr. 34
R. Ergang
W. Herder
Research Areas:
2.3
56. Kraftwerk Union AG
433 Mülheim (Ruhr)
Postfach 1420
H. Schieferstein
Research Areas:
2.2, 2.3, 3.4

57. L. u. C. Steinmüller GmbH
 Mat.-Prüfanstalt
 527 Gummersbach
 S. Pollmann
 Research Areas:
 1.3, 1.5, 2.2, 2.3
58. Mannesmann-Forschungsinstitut GmbH
 41 Duisburg-Wanheim
 Schwenk
 Research Areas:
 1.2, 1.3, 2.3
59. Max-Planck-Institut für Eisenforschung
 4 Düsseldorf
 Max-Planck-Str. 1
 Bohnenkamp
 Research Areas:
 1.2, 1.3, 2.3
60. Max-Planck-Institut für Physikalische Chemie
 34 Göttingen
 Bunsenstr. 10
 Prof. Carl Wagner
 Research Areas:
 1.1, 1.2, 1.3
61. Max-Planck-Institut für Metallforschung
 7 Stuttgart 1
 Seestr. 75
 Dr. H. J. Engell
 H. J. Grabke
 Research Areas:
 1.1, 1.2, 1.3, 2.1, 2.2, 2.3
62. Stahlwerke Südwestfalen AG
 Hüttenal
 5903 Geisweid/Kr. Siegen
 W. Wesseling
 F. W. Frantes
 Research Areas:
 2.1, 2.3
63. Technischer Überwachungsverein Bayern e.V.
 8 München 23
 Kaiserstr. 14
 K. Köhler
 Baumann
 Research Areas:
 2.2, 2.3
64. Technischer Überwachungsverein Essen e.V.
 43 Essen
 Steubenstr. 53
 Baatz
 Hermann
 Research Areas:
 2.2, 2.3, 3.1
65. Thyssen Röhrenwerke AG
 Metallurg. Abteilung
 4 Düsseldorf
 Höherweg 271 a
 E. Kranz
 Research Areas:
 1.1, 2.1, 2.3
66. Universität Bonn
 Mineralogisch-Petrologisches Institut
 53 Bonn 1
 Lichfrauenweg 3
 A. Neuhaus
 N. Gebhardt
 Research Areas:
 1.1, 1.3, 2.2, 2.3
67. Universität Dortmund
 Institut für Physikalische Chemie
 46 Dortmund
 August-Schmidt-Strasse
 H. Ricker
 Research Areas:
 1.1, 1.2, 1.3
68. Universität Karlsruhe
 Institut für Chemische Technik
 75 Karlsruhe
 Kaiserstrasse 12
 Dr. E. Fitzer
 Programs:
 1. Formation of SiO_2 glass layers by oxidation of WSi_2 , MoSi_2 , SiC and Si_3N_4 ; kinetics of the oxidation and the oxygen diffusion through the glass as the controlling step
 2. Kinetics of the reactions of the silicon-donors with base alloys; diffusion of silicon in MeSi_3 -phases; diffusion of basic alloy components to the oxide-forming layers. The following diffusion couples are studied: MoSi_2/Mo , MoSi_2/Nb , MoSi_2/Ta , NbSi_2/Mo , NbSi_2/Nb , WSi_2/Mo , WSi_2/Nb , WSi_2/W , $\text{MoSi}_3/\text{Ta}_2\text{Si}_3$, $\text{MoSi}_3/\text{Nb}_5\text{Si}_3$, $\text{W}_5\text{Si}_3/\text{Nb}_5\text{Si}_3$, Ta/Cr , Nb/Cr , Ta/NiCr , Nb/NiCr
 3. Applied research on the formation of Si-donors on high temperature alloys (for example hot pressing, vapor plating)
 4. Basic research on reactions of refractory silicides with nitrogen; exploration of such compounds as diffusion barriers on Cr-alloys against nitrogen absorption
 5. Mechanical properties and recrystallization behavior of SiO_2 -forming compounds at high temperatures
 6. Compatibility of SiO_2 and Si-donors with oxides of the basic alloys; modifications of SiO_2 -forming compounds by borides and germanides; oxidation kinetics and sintering mechanisms; transport mechanisms in such complex oxides
69. Universität Münster
 Institut für Metallforschung
 Lehrstuhl für Anorganische Analytische Chemie
 44 Münster
 Schlossplatz 2
 F. Umland
 Th. Neumann
 Research Areas:
 1.1, 1.2, 1.3, 2.3, 3.1
70. Verein Deutscher Eisenhüttenleute e.V.
 4 Düsseldorf
 Breite Str. 27
 W. Schlüter
 Research Areas:
 1.1, 1.2, 2.1, 2.2, 2.3
71. Vereinigung der Grosskesselbetreiber
 43 Essen
 Kurfürstenstr. 27
 H. Kirsch
 Research Areas:
 2.3, 3.1
72. Vereinigte Kesselwerke AG
 4 Düsseldorf
 Werdener Str. 3
 Steller
 Research Areas:
 2.3, 3.4

ITALY

73. Ansaldo Meccanico Nucleare
Piazza Garibaldi 2
Genova
L. Boselli
Research Areas:
1.2, 1.3
74. Centro Sperimentale Metallurgico S.p.A. sezione legale
Via di Castel, Romano
Roma
G. Bando
Research Areas:
1.1, 1.2, 2.1, 2.2, 2.3
75. ENIE Nazionale Per l'Energia Elettrica
Via Giovanni Battista Martini
Roma
P. Sturla
Research Areas:
2.2, 2.3, 3.1, 3.4
76. Istituto Metalli Leggeri-Comitato Corrosioni
Via S. Giovanni sul Muro n. 9
Milano
Rossi
Research Areas:
2.3
77. Laboratorio FIAI
Stabilimento Grandi Motori
Corso G. Agnelli 200
Torino
C. Simonetti
Research Areas:
2.3
78. SNAM Progetti
Laboratorio Rinuti Studi e Ricerche
S. Donato Milanese
Milano
C. Verga
Research Areas:
2.3
79. Università di Bologna
Istituto di Metallurgia
Viale Risorgimento, 4
Prof. Paolo Spinedi
Programs:
1. Oxidation of metals in dry oxygen by means of spectrometric and thermogravimetric methods
80. Università di Pisa
Istituto di Chimica Industriale e Applicata
Pisa
M. Baccaredda
Research Areas:
1.3

NETHERLANDS

81. Laboratory for Thermal Power Engineering
Group Combustion Technology and Steamboilers
Rotterdamseweg 139A
Delft
H. van Staai
Programs:
1. Studies of the formation and suppression of V₂O₅-corrosion in fuel-oil fired steamboilers

N.V. tot Keuring van Electrotechnische Materialen (N. V. KEMA)

Vianen
J. H. N. Jelgersma
A. J. Elshout

Research Areas:
1.1, 2.3, 3.1

Technische Hogeschool Twente

P.O. Box 217
Enschede
P. J. Gellins
Research Areas:
1.1, 1.3, 2.3

NORWAY

84. Norges Tekniske Høgskole - NTH
Dep. of Metallurgy
Trondheim
A. B. Winterbottom
Research Areas:
1.1, 1.3

85. Sentralinstitutt for Industriell Forskning - SI
Blindern
Oslo 3
Forskningsveien 1
P. Kofstad
J. Kvernes
Research Areas:
1.1, 1.2, 1.3, 2.1, 2.2, 2.3

SPAIN

86. Celulosas De Huelva, S.A. Madrid
M. R. Ortega
Research Areas:
2.3, 3.1, 3.4

87. Compañia Iberica Rafinadora De Petroleos, S.A.
Madrid
Research Areas:
2.1, 2.3, 3.1, 3.4

88. Esso Petroleos Espanoles, S.A.
Madrid
L. A. Lopez
M. A. Quintana
Research Areas:
2.1, 2.3, 3.1, 3.4

89. La Maquinista Terrestre y Maritima, S.A.
Barcelona
Research Areas:
2.3, 3.1, 3.4

UNITED KINGDOM

90. Admiralty Materials Laboratory
Holton Heath
Poole
Dorset
BH16 6JU
J. F. Conde Lytchett Minster 711
Programs:
1. Study of the phenomenon and mechanism of high temperature sulfidation corrosion in marine gas turbines
2. Studies of alloys and coatings using a low pressure combustion rig
3. Kinetic and other basic investigations

91. Associated Octel Co. Ltd.
Research and Engineering Dept.
P. O. Box 17
Ellesmere Port
Cheshire
W. E. Cowley
Research Areas:
2.1, 2.3
92. Atomic Energy Research Establishment
Harwell
Didcot
Berks
Dr. J. E. Antill Abingdon 4141 Ext. 4454
Programs:
1. Kinetics of the corrosion of metals and ceramics by gases. Particular interests include carburization phenomena and generation of stress by corrosion.
1.1, 2.1, 2.3
93. Babcock, Wilcox (Operations) Ltd.
High Street
Renfrew
Scotland
G. G. Foster
Research Areas:
2.3
94. Berkeley Nuclear Lab., C.E.G.B.
Materials Div.
Berkeley
Gloucestershire
P. P. Jennings
Research Areas:
1.1, 1.2, 1.3, 2.1, 2.2, 2.3
95. British Steel Corp.
Midland Group, Research and Development Dep.
Swinden Laboratories
Moorgate,
Rotherham
A. Nicholson
A. M. Edwards
Research Areas:
1.1, 2.3
96. Brown-Firth, Research Lab.
Attercliffe Road
Sheffield S 4 7VY
J. E. Truman
Research Areas:
2.3
97. Central Electricity Research Lab., C.E.G.B.
Kelvin Avenue
Leatherhead
Surrey
A. B. Hart
D. de G. Jones
D. R. Holmes
W. D. Halstead Leatherhead 4488
Programs:
1. Thermodynamic studies of high temperature corrosion processes
2. Vapor and decomposition pressures of alkali metal sulfates; their vapor and condensed phase reactions. Also those of Fe, Cr, and Ni sulfates, sulfides, V oxides, and mixed sulfates of the type $\text{Na}_3\text{Fe}(\text{SO}_4)_3$.
Research Areas:
1.2, 1.4, 1.5, 2.1, 2.2, 2.3, 3.4
98. The City University
St. John Street
London EC 1
A. C. C. Tseung
Research Areas:
1.3, 2.3
99. Cranfield Institute of Technology (Ex. Glasgow University)
Department of Materials
Cranfield
Bedfordshire
Dr. P. Hancock 0234 51551
Programs:
1. Mechanical properties of surface oxides
2. Influence of surface scales on mechanical properties of underlying metals
3. Effect of gaseous contamination on scaling
100. Fulmer Research Institute Ltd.
Stoke Poges
Buckinghamshire
M. A. P. Dewey Fulmer 2181
Programs:
1. Development of oxidation and sulfidation resistant cobalt and nickel alloys
2. Mechanism of sulfidation attack
3. Physical chemistry of sulfidation
101. Henry Wiggin & Co. Ltd.
Hereford
Dr. J. Heslop Hereford 6461
Programs:
1. High-temperature alloy development
2. Gaseous corrosion
102. Hirst Research Centre, G.E.C. Ltd.
East Lane
North Wembley
Middlesex
D. S. Evans
Research Areas:
1.1, 1.2, 1.3, 2.1, 2.3
103. International Combustion Ltd.
Derby, DE 2, 9 GT
Ashley
Research Areas:
2.1, 2.3
104. International Nickel Ltd.
Research and Development Lab.
Wiggin Street
Birmingham 16
E. G. Richards
Henry Lewis
R. A. Smith 021-454-4871
Programs:
1. Development of new alloys resistant to high-temperature corrosion
2.3
105. University of Leeds
Dep. Metallurgy
The Houldsworth School of Applied Science
Leeds 2
J. C. Scully
Research Areas:
1.3
106. University of Liverpool
Dep. Metallurgy and Materials Science
P. O. Box 147
Liverpool L693BX

- Prof. John Stringer 051-709-6022
 Programs:
 1. Oxidation of tantalum, niobium, and dilute alloys based on these metals
 2. Oxidation and sulfidation of cobalt-base superalloys
 3. Scale fracture mechanisms
 4. Morphologies of oxide scales
 5. Stress generation and relief in growing oxide scales
107. University of Manchester
 Institute of Science and Technology
 Chem. Eng.
 P. O. Box No. 88, Sackville St.
 Manchester M60 1QD
 1. K. Ross
 G. C. Wood 061-236 3311
 I. A. Menzies 061-236 3311
 Programs:
 1. Kinetics, nucleation and growth; structure of oxide scales
 2. Oxidation under wear conditions
 3. Stress and hardness measurements
 4. Cyclic oxidation
 5. Cr and Al diffusion coatings
 6. Mechanical properties of oxides
 7. Sulfidation of Ni-based alloys
108. University of Manchester
 Institute of Science and Technology
 Metallurgy
 P. O. Box No. 88, Sackville St.
 Manchester M60 1QD
 R. Rolls
 Research Areas:
 1.3, 2.2, 2.3
109. Marchwood Eng. Lab., C.E.G.B.
 Marchwood
 Southampton
 Hants
 P. J. Jackson
 Research Areas:
 2.3, 3.1
110. Midlands Region, C.E.G.B.
 Scientific Services Department
 Hams Hall
 Birmingham
 L. H. Toft
 Research Areas:
 2.3, 3.4
111. National Gas Turbine Establishment
 Frestock
 Farnborough
 Hants
 A. Burwood-Smith
 J. I. Northwood
 M. J. Weaver
 Programs:
 1. Effect of alloy composition and microstructure on oxidation
112. National Physical Laboratory
 Teddington
 Middlesex
 G. O. Lloyd 01-977 3222
 Programs:
 1. Microstructural studies of breakaway oxidation on chromium-iron alloys
 2. Hot salt corrosion of nickel-based superalloys
113. University of Newcastle Upon Tyne
 Dep. Metallurgy
 Newcastle-upon-Tyne, 1
 R. F. Tylecote
 D. Maxwell
 Research Areas:
 1.3
114. Nuclear Design and Construction Ltd.
 Cambridge Road
 Whetstone
 Leicester
 D. Goodison
 Research Areas:
 1.3, 2.2, 2.3, 3.1, 3.4
115. N. W. Region, C.E.G.B.
 Scientific Services Department
 825 Wilmslow Road
 East Didsbury
 Manchester
 M. Fountain
 Research Areas:
 1.2, 2.2, 2.3, 3.1
116. Rolls Royce Ltd.
 Bristol Engine Division
 P. O. Box 3
 Filton
 Bristol
 G. Llewellyn
 D. W. Hall
 Research Areas:
 2.2, 2.3
117. University of Sheffield
 Dep. Metallurgy
 St. George's Square
 Sheffield S13JD
 Dr. N. Birks 78555
 Programs:
 1. Oxidation of metals and alloys in complex alloys
118. Shell Research Ltd.
 Thornton Research Centre
 P. O. Box 1
 Chester
 R. W. Wilson
 Research Areas:
 1.2, 1.3, 2.2, 2.3, 3.1, 3.4
- UNITED STATES
119. Aerospace Research Laboratories
 Metallurgy and Ceramics Research Laboratory
 Building 450 (ARZ)
 Wright-Patterson Air Force Base, Ohio 45433
 Dr. N. M. Tallan (513) 255-4402
 Dr. H. C. Graham
 Programs:
 1. Oxidation of ZrB₂, ZrB₂-SiC, and ZrB₂-SiC-C compositions
 2. Oxidation of dispersion-strengthened Ni-Cr alloys
 3. Oxidation/vaporization of Cr₂O₃
 4. Effect of rare earth additions on oxidation of Ni-Cr-Al alloys
 5. Oxidation of coated columbium-based alloys
 6. High temperature oxidation of alloys containing Mo and/or W
 7. Sulfidation and hot corrosion
 8. Diffusion in oxide scales.

120. AiResearch Manufacturing Company of Arizona
 Division of The Garrett Corp.
 402 South 36th Street
 Phoenix, Arizona 85034
 M. S. Roush (602) 267-2650
 Programs:
 1. Evaluation of seven commercial protective coatings for resistance to hot corrosion
 2. Investigation of repair of diffusion coatings on turbine components
 3. Investigation of the relative hot-corrosion resistance of uncoated and coated IN-738, IN-792, MAR-M 432, MAR-M 509, as compared with IN-100 and Alloy 713LC
121. Air Force Institute of Technology
 Civil Engineering School
 Wright-Patterson Air Force Base, Ohio 45433
 Dr. James R. Myers (513) 255-3569
 Programs:
 1. Coatings for superalloys in gas turbine engines
 2. Oxidation of ultra-pure cobalt at selected oxygen pressures over the temperature range 950 - 1250 C
 3. The oxidation of René 41 and thoriated nickel filaments
122. Avco Corporation
 Systems Division
 Materials Sciences Dept.
 Lowell Industrial Park
 Lowell, Massachusetts 01851
 Dr. Warren C. Steele (617) 452-8961
 Programs:
 1. Kinetics of gas-surface reactions (Reactions of refractory metals or coated metals with high temperature air species)
 2. Graphite oxidation
123. Avco Lycoming Division
 Materials Laboratories Dept.
 550 So. Main Street
 Stratford, Connecticut 06497
 Dr. William R. Freeman, Jr. (203) 378-8211
 Programs:
 1. Evaluation of promising sulfidation resistant nickel-base superalloys
 2. Effect of time, sulfur content, NaCl content, temperature, and alloy composition on depth of attack
 3. Effect of vanadium and NaCl on corrosion rate
124. Battelle Memorial Institute
 Columbus Laboratories
 505 King Avenue
 Columbus, Ohio 43201
 Dr. R. I. Jaffee (614) 299-3151 Ext. 1536
 E. S. Bartlett (614) 299-3151 Ext. 2873
 Dr. B. A. Wilcox (614) 299-3151 Ext. 2360
 Programs:
 1. Oxidation of superalloys, particularly cobalt-base alloys, and dispersion strengthened nickel-base alloys, such as TD NiC and TD NiCrAl
 2. Studies on the effects of ThO₂ and rare earth metals and their oxides on oxidation mechanisms in nickel and cobalt alloys
 3. Diffusion studies of metals in oxides and alloys Cr³⁺ in NiO and NiCr and Al³⁺ in TD NiCrAl alloys
 4. Creep in oxides
 5. Plasticity in scales
 6. Oxidation of tantalum, columbium, and their alloys
 7. Evaluation of coated refractory materials
125. Bell Telephone Laboratories
 Dept. of Metallurgical Engineering
 Room 1A-106
 Murray Hill, New Jersey 07974
 Dr. J. H. Swisher (201) 582-4601
 Programs:
 1. Internal oxidation as a means of dispersion strengthening alloys for high-temperature cations
 2. Surface oxidation of Ni-Fe alloys containing small Si and Mn additions. Controlled surface oxidation required for electrical contacts
 3. Corrosion in thin film metallization
126. Bendix Research Laboratories
 Materials and Processes Dept.
 16-1/2 Mile Road
 Southfield, Michigan 48075
 S. K. Rhie (313) 352-7630
 Programs:
 1. Oxidation of commercial high-temperature alloys
127. Bureau of Mines
 Materials Science Projects
 Albany Metallurgy Research Center
 P.O. Box 70
 Albany, Oregon 97321
 Dr. Arne Landsberg (503) 926-5811
 Dr. Laurance L. Oden (503) 926-5811
 Programs:
 1. Chlorination of gold
 2. Chlorination of platinum
 3. Chlorination of tungsten, molybdenum and their binary alloys
 4. Materials for construction of high temperature chlorinators (under which title the corrosion of the alkaline earth fluorides in typical industrial chlorination environments was investigated)
128. Cabot Corporation
 Stellite Division
 Technology Dept.
 1020 W. Park Avenue
 Kokomo, Indiana 46901
 Dr. S. T. Wiodek (317) 457-8411 Ext. 624
 Programs:
 1. Development of high strength Ni- and Co-base alloys with good oxidation/hot corrosion resistance
 2. Evaluation of commercial Ni- and Co-base alloys in oxidation/heat corrosion
 3. Development of alloys for carbonizing/oxidizing service
 4. Processing techniques for highly alloyed oxidation resistant compositions
129. Clemson University
 College of Engineering
 Clemson, South Carolina 29631
 Dr. James S. Wolf
 Programs:
 1. The role of self-generated scale stresses in the high-temperature oxidation of metals

130. Connecticut, University of
Department of Metallurgy
Storrs, Connecticut 06268
Dr. J. F. Deveraux (203) 429-3311 Ext. 1273
Prof. N. D. Greene (203) 429-3311 Ext. 1273
Programs:
1. Effect of oxide contaminants on oxidation of silicon
2. Oxidation of lanthanide metals
131. Curtiss-Wright Corporation
Materials Engineering Dept.
One Passaic Street
Wood-Ridge, New Jersey 07075
Mr. Sam Wolsin (201) 777-2900 Ext. 2709
Programs:
1. Evaluation of diffusion coatings for Udimet 700
2. Evaluation of diffusion coatings for IN-100
3. Evaluation of the relative oxidation-hot corrosion resistance of selected nickel- and cobalt-base superalloys
4. Development of improved diffusion coatings for nickel- and cobalt-base superalloys
132. Dayton, University of
Research Institute
High Temperature Materials Engineering Group
Dayton, Ohio 45409
Dr. Dennis Gerdean (613) 229-2517
Programs:
1. Creep of coated and uncoated Ta-222 (current)
2. Repairability of slurry silicide coatings (inactive)
133. Delaware, University of
Department of Chemical Engineering
Newark, Delaware 19711
Prof. C. L. Birchall
Programs:
1. Diffusion of Fe⁵⁵ in Cr₂O₃
2. Self-diffusion of iron in ferrous sulfide
134. Denver, University of
Metallurgy and Materials Science Division
Denver Research Institute
University Park
Denver, Colorado 80210
Dr. Albert S. Yamamoto (303) 753-2621
Programs:
1. Development of Ni-Cr-W alloys with emphasis on improved oxidation and sulfidation resistance (recently completed)
135. Florida, University of
Dept. of Metallurgical and Materials Engineering
Center for Applied Thermodynamics and Corrosion
Gainesville, Florida 32601
F. N. Rhines (304) 392-1451
F. R. Verink (304) 392-1451
Programs:
1. Oxidation of nickel
2. Surface films
136. Ford Motor Company
Materials Development Dept.
Turbine Operations
20000 Rotunda Drive
Dearborn, Michigan 48121
Yesta P. Jelang (313) 32-31612
Warren A. Rentz (313) 33-75316
Programs:
1. Development of high-temperature nickel- and cobalt-base alloys and determination of their properties
2. Improved sulfidation resistant coatings for nickel-base alloys
137. General Electric Company
Materials and Processes Laboratory
Schenectady, New York 12305
Dr. Chester T. Sims (518) 374-2211
Ext. 5-3079, 5-9223
Gerald Wasielewski
Programs:
1. Development of nickel- and cobalt-base alloys for industrial gas turbines
2. Correlation of oxidation/corrosion test data with service life for superalloys and steels
3. Development of hot-corrosion resistant alloys for marine gas turbines (Navy/MEL)
4. Study of fuel treatments for residual fuels
5. Materials developments for hot-stage use in residual fuel marine industrial turbines
138. General Electric Company
Material and Process Technology Laboratories
Thomson Laboratory
1000 Western Ave.
Lynn, Massachusetts 01905
Dr. M. Kaufman (617) 594-5156
E. J. Beltran
Programs:
1. Hot corrosion behavior of nickel- and cobalt-base superalloys and protective coatings in simulated marine and industrial environments
139. General Electric Company
Oxidation/Corrosion Laboratory
Materials Development Engineering
Gas Turbine Department #53-337
Schenectady, New York 12305
Harvey von E. Doering (518) 374-2211
Ext. 54311
Programs:
1. Development of high temperature (1400 - 2000 oxidation data for design properties
2. Evaluation of nickel- and cobalt-base alloys and coatings in crude and residual fuels
3. Evaluation of nickel- and cobalt-base alloys and coatings in hot corrosion
4. Evaluation of corrosion inhibiting additives for vanadium bearing fuels
140. General Electric Company
Research and Development Center
Metallurgy and Ceramics Laboratory
P.O. Box 8
Schenectady, New York 12301
Dr. C. S. Tedmon Jr. (518) 346-8771
Dr. H. S. Spacil (518) 346-8711
Dr. Alan U. Seybolt (518) 346-8771
Programs:
1. Thermodynamics and kinetics of corrosion of gas turbine alloys burning impure fuel
2. Research on mechanisms of hot corrosion
141. General Electric Company
Materials and Process Technology Laboratory
Aircraft Engine Group
Building 500-M87
Cincinnati, Ohio 45215
Dr. William C. Hagel
C. S. Wukusick
Programs:
1. Hot corrosion and oxidation of superalloys
142. General Electric Company
Materials and Processes Laboratory
Aircraft Engine Group
Evendale, Ohio 45218
Dr. R. E. Allen (513) 243-6738

Programs:

1. Strengthening of FeCrAlY oxidation resistant alloys
2. The influence of high velocity (Mach 0.5-1.0) gases on surface stability in high-temperature alloys
3. Oxidation resistance and coating development for high strength Cr alloys
4. Coating development for TD NiCr
5. The influence of small quantities of rare earth elements on the oxidation resistance of Ni-base superalloys

143. IIT Research Institute

Metals Division
10 West 35th Street
Chicago, Illinois 60616
Dr. V. L. Hill (312) 225-9630

Programs:

1. Development of oxidation-resistant hafnium-base alloys (current)
2. Investigation of refractory metal composites for liquid rocket engines (oxidation-corrosion in O₂, F₂, HF, BF₃ and their combinations) (current)
3. Ductile claddings for dispersion-strengthened nickel-base alloys (oxidation of Ni-Cr-Al-Y, Ni-Cr-Ta-Y, and Fe-Cr-Al-Y Alloys) (Completed)

144. The International Nickel Company, Inc.

Paul D. Merica Research Laboratory
Materials Systems Section
Sterling Forest
Suffern, New York 10501
Dr. J. W. Schultz (914) 735-2761

Programs:

1. Improved test methods for hot-corrosion and oxidation
2. Effects of alloy composition on hot corrosion and oxidation resistance of nickel-base alloys

145. Little, A. D., Inc.

R&D Division, Materials Section
Cambridge, Massachusetts 02140
Dr. Joan B. Berkowitz (617) 864-5770 Ext. 2913

Programs:

1. Effects of electric fields on hot corrosion in conducting flames

146. Lockheed Missiles & Space Company

Palo Alto Research Laboratories
Metallurgy and Composites, D/S2-31, B/204
3251 Hanover Street
Palo Alto, California 94304

Dr. T. E. Tietz (415) 324-3311 Ext. 45678
R. A. Perkins (415) 324-3311 Ext. 45740
C. M. Packer (415) 324-3311 Ext. 45286

Programs:

1. Stability characterization of refractory materials under high velocity flight conditions (Air Force)
2. Nitridation resistant chromium alloys (NASA)
3. Coatings for tantalum alloys (NASA)
4. Environmental stability of high temperature alloys (IR&D)

147. Los Alamos Scientific Laboratory

Group X-1
P.O. Box 1663
Los Alamos, New Mexico 87544
Dr. R. J. Fries (505) 667-6322

Programs:

1. Chemical diffusion coefficients of carbon in the Group VI refractory metals as determined from carbide layer growth rates
2. Carbide layer growth rates of W/Mo and W/Re alloys
3. Evaporation rates of refractory metals

148. Manlabs, Inc.

21 Erie Street
Cambridge, Massachusetts 02139
Dr. L. Kaufman

Programs:

1. Stability characterization of refractory materials under high velocity atmospheric flight conditions
2. Development of boride composites for oxidation resistant components

149. Massachusetts Institute of Technology

Corrosion Laboratory
Room 8-202
Cambridge, Massachusetts 02139
Prof. Herbert H. Uhlig (617) 864-6900 Ext. 5315

Programs:

1. Initial oxidation of single crystal copper (150-250 °C)

150. Michigan, University of

Department of Chemical and Metallurgical Engineering
Ann Arbor, Michigan 48104
Prof. Lawrence H. Van Vlack (313) 764-2385

Programs:

1. Oxide subscales in binary iron alloys
2. Scale and subscale formation in alloys of iron with Group VIIB elements

151. NASA-Lewis Research Center

Coating Section, 49-1
21000 Brookpark Road
Cleveland, Ohio 44135
Salvatore J. Grisaffee (216) 433-4000 Ext. 393

Programs:

1. Pack and slurry coatings for superalloys and dispersion strengthened materials
2. Alloy claddings for superalloys and dispersion-strengthened metals
3. Oxidation behavior of coatings and metal claddings
4. Characterization of coatings and metal claddings
5. Development and evaluation of slurry coatings for refractory metals
6. Coatings for high performance rocket engines
7. Hot corrosion of alloys

152. NASA Lewis Research Center

Oxidation and Refractory Compounds Section, 49-1
21000 Brookpark Road
Cleveland, Ohio 44135
Dr. H. B. Probst (216) 433-4000 Ext. 267

Programs:

1. Oxidation of TD Nickel-Chromium
Surface preparation effects
Velocity effects
Pressure effects
Scale topology
Hot corrosion
2. Oxidation mechanisms and kinetics in the Ni-Al, Ni-Al-Cr, Ni-Al-Ti, and Ni-Al-Si systems
3. Simulated turbine engine oxidation of commercial cast Ni-base superalloys
4. Vaporization of protective scales

5. Cyclic oxidation of Cr₂O₃ and Al₂O₃ forming alloys
 6. Properties of spinels
 7. Coating and cladding studies
153. National Bureau of Standards
Corrosion Section
 Washington, D. C. 20234
 Dr. J. Kruger (301) 921-2094
 Programs:
 1. Surface reactions and initial film formation
154. Naval Air Development Center
 Mechanical Metallurgy Branch (MAMM-4)
 Metallurgical Division
 Aero Materials Department
 Warminster, Pennsylvania 18974
 Robert G. Mahorter (215) 672-9000 Ext. 2808
 Programs:
 1. Analyses of parts from engines subjected to naval aircraft service to determine the extent and severity of oxidation/corrosion problems
 2. Studies of surface reaction kinetics with the objective of minimizing scale formation on heat resisting alloys
 3. Development of NDT methods for detecting incipient hot corrosion
155. Naval Ship Research and Development Laboratory
 Metals and Composites Division
 Code A815
 Annapolis, Maryland 21402
 Walter L. Wheatfall, Sr. (301) 268-7711
 Ext. 8205
 Programs:
 1. Hot corrosion behavior of recently developed nickel-base alloys in combustion products from diesel fuel
 2. Oxidation behavior of nickel-base superalloys
 3. Development of dispersion-strengthened cobalt-base alloys
 4. Effect of fuel additives on hot-corrosion behavior of materials in combustion products of vanadium-bearing fuels plus ingested sea salt
 5. Effect of alloying elements on hot-corrosion behavior of nickel-base alloys
 6. Mechanism of hot corrosion
156. New York, State University of
 Dept. of Materials Science
 College of Engineering
 Stony Brook L. I., New York 11790
 Prof. L. Seigle
 Programs:
 1. Mechanism of oxidation of Ni-Al alloys
157. North American Rockwell Corp.
 Science Center
 Thousand Oaks, California 91360
 Dr. Neil Paton (805) 498-4545
 Programs:
 1. Oxidation of thoria-dispersed nickel-base alloys
 2. Hot salt stress corrosion of superalloys
158. Northwestern University
 Department of Materials Science
 The Technological Institute
 Evanston, Illinois 60201
 Prof. J. Bruce Wagner, Jr.
 Programs:
 1. The diffusion of sulfur and also the diffusion of chlorine in single crystals of oxides
159. The Ohio State University
 Dept. of Metallurgical Engineering
 116 W. 19th Avenue
 Columbus, Ohio 43210
 Prof. Robert A. Rapp (614) 293-6178
 Programs:
 1. Oxidation of Ni-Cr-Al alloys at 1000-1200 C
 2. Solubility and diffusivity of oxygen in solid nickel
 3. Diffusion of chromium in nickel oxide
 4. Control of oxygen activity in gaseous environments
160. Olin Corporation
 Metals Research Laboratories
 91 Shelton Avenue
 New Haven, Connecticut 06511
 Dr. M. J. Pryor
 Programs:
 1. High-temperature oxidation of copper-base alloys
161. Pennsylvania State University
 Metallurgy Section
 M. I. Building
 University Park, Pennsylvania 16802
 Prof. G. Simkovich (814) 865-3351
 Programs:
 1. Sulfidation of binary and ternary iron-base alloys
 2. Oxidation of chromium-base alloys
 3. Oxidation of cast irons
 4. Oxidation and sulfidation of pure metals
 5. Oxidation and simultaneous carburization of pure metals and alloys
 6. Effect of gas solubilities in scales upon kinetics of oxidation and sulfidation
162. Pennsylvania, University of
 School of Metallurgy and Materials Science
 Philadelphia, Pennsylvania 19104
 Prof. W. L. Worrell (215) 594-8592
 Programs:
 1. Kinetics of dissociation of H₂S(g) on iron sulfide (FeS) at elevated temperatures
 2. Nitridation of titanium at temperatures between 1200 and 1500 C
 3. High-temperature corrosion of chromium and chromium-nickel alloys in SO₂/O₂ atmospheres
163. Phillips Petroleum Company
 Research and Development Dept.
 Phillips Research Center, Bldg. C-7
 Bartlesville, Oklahoma 74003
 R. M. Schirmer (918) 336-6600 Ext. 48-573
 Programs:
 1. Effect of sulfur in JP-5 fuel on hot corrosion of turbine blade materials in marine environment
 2. Evaluation of protective coatings for resistance to hot corrosion
 3. Effect of smoke-abatement additives in JP-5 fuel on hot corrosion of turbine blade materials
 4. Development of turbine simulator for hot corrosion studies
 5. Inhibition of hot corrosion of superalloys by fuel additives
 6. Effect of pressure on hot corrosion of superalloys
 7. Effect of vanadium in fuel on hot corrosion of superalloys
 8. Effect of lead in fuel on hot corrosion of superalloys

164. Pratt & Whitney Aircraft
 Division of United Aircraft Corp.
 Advanced Materials Research and Development
 Laboratory
 Middletown, Connecticut 06457
 Dr. F. S. Pettit (302) 347-4401 Ext. 3189
 Dr. G. W. Goward (302) 347-4401 Ext. 3189
 Pratt & Whitney Aircraft Div.
 East Hartford, Conn.
 Dr. D. H. Boone
 Programs:
 1. Oxidation and hot corrosion (Na_2SO_4 , etc.) of nickel- and cobalt-base alloys--development of more resistant alloys
 2. Protective coatings for nickel- and cobalt-base alloys
 3. Oxidation of uncoated and coated columbium-base alloys
165. Purdue University
 School of Materials Science and Metallurgical Engineering
 Lafayette, Indiana 47907
 Prof. Richard E. Grace (317) 749-2601
 Programs:
 1. Transition kinetics during linear to parabolic oxidation of chromium (recently completed)
 Oxidation-sulfidation kinetics of iron (current)
166. Solar Division
 International Harvester Company
 Process Research Dept. (Mail Zone R-1)
 2200 Pacific Highway
 San Diego, California 92112
 A. R. Stetson
 Programs:
 1. Castings for dispersion strengthened alloys--NAS3-14312
 2. Fused slurry silicide coatings for Ta reentry heat shields--NAS3-14315
 3. Evaluation of coatings for cobalt- and nickel-base superalloys--NAS3-9401
 4. Silicide coatings for tantalum and columbium alloys--NAS3-9412 and NAS3-7276 (NASA CR-72519 and NASA CR-54529)
 5. Hot corrosion of coated superalloys in a gas turbine environment, Contract No. N00019-68-C 0532 (Naval Air System Command AIR 53674)
167. Stanford Research Institute
 Materials Sciences Laboratory
 Menlo Park, California 94025
 Dr. Daniel D. Cubicciotti (415) 326-6200
 Programs:
 1. Volatilization of metal oxides and thermodynamics of oxides
 2. Hot salt corrosion
 3. Reactions with salts and oxides
168. Stanford University
 Mineral Engineering Dept.
 Stanford, California 94305
 Prof. R. W. Bartlett (415) 321-2500 Ext. 4470
 Programs:
 1. Solubility and diffusion of oxygen in platinum and the effect of other metals in platinum alloys on both internal oxidation and oxygen transport. The end applications are related to high temperature coatings based on platinum group metals. (current)
169. Sylvania Electric Products, Inc.
 Chemical and Metallurgical Division
 High Temperature Composites Laboratory
 70 Cantiague Road
- Hicksville, New York 11802
 Lawrence Sama (516) 931-3500
 Programs:
 1. Development of protective coatings for columbium alloy gas turbine blades
 2. Scale-up of fused silicide coatings for columbium alloy reentry heat shields
170. Systems Research Laboratories, Inc.
 Physical Sciences Division
 7001 Indian Ripple Road
 Dayton, Ohio 45440
 Dr. W. C. Tripp (513) 426-6000
 Programs:
 1. Electrical behavior of ceramic materials at high temperatures (includes study of defect structure and high temperature oxidation of metals and alloys)
171. TRW, Inc.
 Equipment Group
 23555 Euclid Avenue
 Cleveland, Ohio 44117
 Dr. J. V. Peck (216) 383-2967
 Dr. R. J. Quigg
 Programs:
 1. Aluminide coatings on superalloys
 2. Non-aluminide coatings for superalloys
 3. Coatings for columbium
 4. Basic corrosion of superalloys
 5. Development of production manufacturing techniques for coating Ti-Ni
 6. Development of repair and reprocess coating for Ni-base alloy turbine blades
 7. Development of improved coatings for Ni- and Co-base alloys
 8. Manufacturing techniques for W/Si-W coated tantalum
172. United Aircraft Research Laboratories
 High Temperature Materials Research
 400 Main Street
 East Hartford, Connecticut 06108
 Dr. Michael A. DeCrescente
 N. Bornstein
 Programs:
 1. Sulfidation mechanisms
 2. Mechanism of vanadium accelerated corrosion
 3. High temperature oxidation
173. United States Steel Corporation
 Applied Research Laboratory MS-16
 P.O. Box 38
 Monroeville, Pennsylvania 15146
 Dr. W. E. Boggs (412) 372-1212
 Dr. E. H. Phelps
 Programs:
 1. Investigation of the reactions between hot sulfur-containing gases and iron base alloys (current)
 2. The modification and inhibition of oxide formed on steel in slab reheat furnaces (current)
 3. Effects of alloying elements on the formation of protective oxide films on heat resistant steels (terminated 1970)
 4. Evaluation of high-temperature oxidation performance of ferrous alloys
 5. Development of coatings for oxidation resistance
174. United States Steel Corporation
 Physical Chemistry Section
 Edgar C. Bain Laboratory for Fundamental Research
 Research Center
 Monroeville, Pennsylvania 15146

175. Prof. Edward W. Pickering (412) 331-3100
Programs:
1. Transition from internal to external oxidation in binary and ternary alloys
2. Preferential attack of one component of binary alloys by an aggressive gas
176. University of California at Los Angeles
Materials Department
6551 Boelter Hall
Los Angeles, California 90024
Prof. D. L. Douglass (213) 825-1622
Programs:
1. Zirconium oxidation mechanism
2. Role of oxide plasticity on oxidation
3. Influence of rare earth metals on oxidation
4. Resistance of Ni-20Cr and Ni₃Al
176. Vanderbilt University
Dept. of Materials Science and Metallurgical Eng.
Nashville, Tenn. 37203
Prof. B. D. Lichter (613) 322-2415
Programs:
1. Hot corrosion mechanisms in Ni-Cr alloys and superalloys
2. Effect of rare-earth oxide additions on hot corrosion of Ni-Cr alloys
177. Westinghouse Electric Corp.
Astronuclear Laboratory
Metals Science Section
P.O. Box 10884
Pittsburgh, Pennsylvania 15236
Dr. R. C. Svedberg (412) 892-5600
- Programs:
1. Investigation of the possibility of modifying the defect structure of parent oxides to enhance oxidation protection (NASC No. N00019-70-C-0148) (current)
2. Reactivity of some vanadium alloys with the interstitials oxygen, nitrogen, and carbon at low partial pressures (AEC Contract AT(30-1)-3791 (completed))
3. Evaluation of mechanical properties, oxidation resistance and structure of slurry-silicide coated T-222 (NASA-CR-72713) Contract No. NAS3-12410 (completed)
4. Development of ductile oxidation resistant columbium alloy (AFML-TR-69-64) Contract No. AF33615-67-C-1689 (completed)
178. Westinghouse Electric Corporation
Westinghouse Research Laboratories
Churchill Borough
Pittsburgh, Pennsylvania 15235
Dr. Earl A. Gulbransen (412) 256-3475 or 3482
Programs:
1. Vaporization chemistry in the oxidation of Cr, Si, Mo and Cb
2. Thermochemistry and the high temperature oxidation of Si and SiC
3. Thermochemistry and the reaction of metals with S and O gases
4. High temperature oxidation of refractory metals
5. Thermochemistry and the combustion of aluminum and zirconium

TABLE 2. CATEGORY INDEX

Category*	Code*	Organization (Number from Table 1)	Total
Thermodynamics, phase diagrams, reaction equilibria	1.1	1,3,5,6,13,14,19,20,22,26,27,31,32,37,39,41,42,43,44,49,53,54,60,61,65,66,67,69,70,74,82,83,84,85,92,94,95,97,99,100,102,106,107,119,124,129,130,135,147,152,155,156,159,167,168,171,172,173,174,175,178	61
Electrochemical problems	1.2	1,14,20,23,28,43,50,54,58,59,60,61,67,69,70,73,74,85,94,97,102,115,118,145	24
Reaction kinetics and diffusion processes	1.3	2,3,5,6,9,10,11,13,14,15,17,19,21,26,28,30,31,32,37,38,39,40,41,42,43,44,48,49,51,53,54,57,58,59,60,61,66,67,68,69,73,79,80,83,84,85,90,92,94,97,98,99,100,102,105,106,107,108,112,113,114,117,118,119,121,122,124,125,127,130,133,135,140,141,142,144,147,149,150,152,153,154,155,156,158,159,161,162,165,167,171,172,173,174,175,177,178	97
Aerodynamic factors (mechanism of deposition)	1.4	97,146,148,152	4
Rheological investigations (viscosity of the melts)	1.5	48,57,97	3
Development of corrosion-resistant materials	2.1	2,18,22,24,32,36,47,52,53,61,62,65,70,74,85,87,88,91,92,94,97,100,101,102,103,104,106,107,111,119,124,128,134,136,137,142,143,146,148,155,176,177	42
Surface protection of materials	2.2	5,6,7,8,15,16,19,22,24,27,29,30,32,33,34,35,40,49,51,56,57,61,63,64,66,68,70,74,75,85,90,94,97,107,108,114,115,116,118,119,120,121,124,131,132,136,138,139,142,143,146,151,152,163,164,166,168,169,171,177	60
Material Behavior under corrosion	2.3	2,3,4,5,6,8,11,12,13,14,15,16,17,19,22,24,25,33,39,40,45,46,47,49,50,51,52,53,54,55,56,57,58,59,61,62,63,64,65,66,69,70,71,72,74,75,76,77,78,81,82,83,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,101,102,103,104,106,107,108,109,110,111,112,114,115,116,117,118,119,120,121,123,124,126,127,128,131,137,138,139,140,141,143,144,146,150,151,152,154,155,157,159,160,161,162,163,164,166,170,171,174,175,176,177	119
Additives	3.1	48,49,53,64,69,71,75,82,86,87,88,89,109,114,115,118,139,163	18
Surface treatment of pipes, supports, and other parts of furnaces, boilers,, turbines, etc. exposed to high temperatures	3.4	2,7,49,53,56,72,75,86,87,88,89,97,110,114,118	15

*The categories and code numbers were selected to conform to those of the European Federation of Corrosion survey.

TABLE 3. NAME INDEX

Ahlborn, H. Battelle-Institut e.V. (47)	Bohnenkamp, Max-Planck-Institut für Eisenforschung (59)
Allen, Dr. R.E. General Electric Co. (142)	Boone, Dr. D.H. Pratt & Whitney Aircraft (164)
Antill, Dr. J.L. Atomic Energy Research Establishment (92)	Bornstein, N. United Aircraft Research Lab. (172)
Ashley, International Combustion Ltd. (103)	Boselli, B. Ansaldo Meccanico Nucleare (73)
Baatz, Technischer Überwachungsverein Essen e.V. (64)	Brabers, Dr. M.J. Katholieke Universiteit Leuven (6)
Baccaredda, M. Università di Pisa (80)	Bruch, J. Edelstahlwerk Witten AG (52)
Bando, G. Centro Sperimentale Metallurgico S.p.A. sede legale (74)	Brinnetaud, SNECMA (33)
Bardolle, J. Université d'Orléans (41)	Buckle, H. Office National d'Etudes et de Recherches (32)
Barret, P. Laboratoire de Recherche sur la Réactivité des Solides associé au CNRS (31)	Bungardt, Dr. K. Deutsche Edelstahlwerke AG (51)
Bartlett, E.S. Battelle Columbus Laboratories (124)	Burwood-Smith, A. National Gas Turbine Establishment (111)
Bartlett, Prof. R.W. Stanford University (168)	Buskens, H. Babcock-Werke (46)
Baumann, Technischer Überwachungsverein Bayern e.V. (63)	Caplan, Donald National Research Council of Canada (14)
Belin, P. Université de Tours (44)	Casteels, F. Centre D'Etude de L'énergie Nucléaire (9)
Beltran, E.J. General Electric Co. (138)	Condé, J.F.G. Admiralty Materials Laboratory (90)
Benard, J. Ecole Nationale Supérieure de Chimie de Paris (27) (42)	Coutsouradis, D. Centre de Recherches Métallurgiques (2)
Beranger, G. Centre de Recherches Métallurgiques de l'Ecole des Mines (23)	Cowley, W.E. Associated Octel Co. Ltd. (91)
Berkowitz, Dr. Joan B. A.D. Little, Inc. (145)	Cox, B. Atomic Energy of Canada, Ltd. (10)
Besson, Ecole Nationale Supérieure Electrochimie et Electrometallurgie (28)	Cubicciotti, Dr. Daniel D. Stanford Research Institute (167)
Birchenall, Prof. C.E. University of Delaware (133)	Darras, R. Centre d'Etudes Nucléaires de Saclay (21)
Birks, Dr. N. University of Sheffield (117)	Davin, A. Centre National de Recherches Métallurgiques (2)
Boggs, Dr. W.E. U.S. Steel Corp. (173)	DeCrescente, Dr. Michael A. United Aircraft Research Lab. (172)
	Detfet, L. Institut Belge des Hautes Pressions (4)

- Devereux, Dr. O.F.
University of Connecticut (130)
- Dewey, M.A.P.
Fulmer Research Institute Ltd. (100)
- Doering, Harvey von E.
General Electric Co. (139)
- Douglass, Prof. D.L.
University of California at Los Angeles (175)
- Dreschler,
Université de Marseille (39)
- Edwards, A.M.
British Steel Corp. (95)
- Elshout, A.J.
N.V. tot keuring van Electrotechnische Materialien (82)
- Engell, Dr. H.J.
Max-Planck-Institut für Metallforschung (61)
- Ergang, R.
International Nickel Deutschland GmbH (55)
- Evans, D.S.
Hirst Research Centre, G.E.C. Ltd. (102)
- Ferre,
SNECMA (33)
- Fitzer, Dr. E.
Universität Karlsruhe (68)
- Fountain, M.
N.W. Region C.E.G.B. (115)
- Foster, G.G.
Babcock, Wilcox Ltd. (93)
- Frantes, F.W.
Stahlwerke Südwestfalen AG (62)
- Freeman, Dr. W.R. (Jr.)
Avco Lycoming (123)
- Fries, Dr. R.J.
Los Alamos Scientific Laboratory (147)
- Galmiche, P.
Office National d'Etudes et de Recherches (32)
- Gebhardt, N.
Universität Bonn (66)
- Gellins, P.J.
Technische Hogeschool Twente (83)
- Gerdeman, Dr. Dennis
University of Dayton (132)
- Givord, J.P.
Société Ugine-Kuhlmann (35)
- Glaverbel, S.A.
Laboratoire Central (8)
- Goodison, D.
Nuclear Design and Construction Ltd (114)
- Goward, Dr. G.W.
Pratt & Whitney Aircraft (164)
- Grabke, H.J.
Max-Planck-Institut für Metallforschung (610)
- Grace, Prof. Richard E.
Purdue University (165)
- Graham, Dr. H.C.
Aerospace Research Laboratories (119)
- Greene, Prof. N.D.
University of Connecticut (130)
- Gregoire,
Ecole Centrale des Arts et Manufactures (25)
- Grisaffee, Salvatore J.
NASA-Lewis (151)
- Grönlund, N.F.
Universität von Kopenhagen (20)
- Gulbransen, Dr. Earl A.
Westinghouse Electric Corp. (178)
- Habraken, L.
Centre de Recherches Metallurgiques (2)
- Hagel, Dr. William C.
General Electric Co. (141)
- Hall, D.W.
Rolls Royce Ltd. (116)
- Halstead, W.D.
Central Electricity Research Lab., C.E.G.B. (97)
- Hancock, Dr. P.
Cranfield Institute of Technology (99)
- Hart, A.B.
Central Electricity Research Lab., C.E.G.B. (97)
- Hermann,
Technischer Überwachungsverein Essen e.V. (64)
- Heslop, Dr. J.
Henry Wiggin & Co. Ltd. (101)
- Hestermans, P.
Institut Belge des Hautes Pressions (4)
- Heumann, Th.
Universität Munster (69)
- Hill, Dr. V.L.
IIT Research Institute (143)

- Hivert, A.
Office National d'Etudes et de Recherches (32)
- Holmes, D.R.
Central Electricity Research Lab., C.E.G.B. (97)
- Lackson, P.J.
Marchwood Eng. Lab., C.E.G.B. (109)
- Tatfee, Dr. R.I.
Battelle Columbus Laboratories (124)
- Jahn, H.
Babcock-Werke (46)
- Jelgersma, J.H.N.
N.V. tot keuring van Electrotechnische Materialien (82)
- Jennings, P.P.
Berkeley Nuclear Lab., C.E.G.B. (94)
- Jones, D. de G.
Central Electricity Research Lab., C.E.G.B. (97)
- Kaufman, Dr. I.
ManLabs, Inc. (148)
- Kaufman, Dr. M.
General Electric Co. (138)
- Kirsch, H.
Vereinigung der Grosskesselbetreiber (71)
- Korstad, P.
Sentralinstitutt for Industriell Forskning (85)
- Kohler, K.
Technischer Überwachungsverein Bayern e.V. (63)
- Kranz, E.
Thyssen Röhrenwerke AG (65)
- Kruger, Dr. J.
National Bureau of Standards (153)
- Kvernes, J.
Sentralinstitutt for Industriell Forskning (85)
- Lacombe, P.
Centre de Recherches Metallurgiques de l'Ecole des Mines (23)
- Lafitte, M.
Université de Marseille (39)
- Landsberg, Dr. Arne
Bureau of Mines (127)
- Legendre, P.
Centre de Recherches de la Société Métallurgique d'Imphy (24)
- Lehr, P.
Centre National de la Recherche Scientifique (22)
- Fennartz, Dr. G.
Deutsche Edelstahlwerke AG (51)
- Lewis, Henry
International Nickel Ltd. (104)
- Lichter, Prof. B.D.
Vanderbilt University (175)
- Llewellyn, G.
Rolls Royce Ltd. (116)
- Lloyd, G.O.
National Physical Laboratory (112)
- Lopez, L.A.
Esso Petroleos Espanoles (88)
- Mahorter, Robert G.
Naval Air Development Center (154)
- Mailhos, M.
Forges et Acieries du Saut du Tarn (29)
- Manenc, J.
Institut de Recherches de la Sidérurgie (30)
- Marion, F.
Université d'Amiens (37)
- Maxwell, D.
University of Newcastle-Upon-Tyne (113)
- Menzies, Ian A.
University of Manchester (107)
- Molinier,
Trefimetaux G.P. (36)
- Möller, H.
Brown, Boveri & Cie. (49)
- Möller, W.
Forschungsvereinigung Verbrennungskraftmaschinen (53)
- Morris, Dr. L.A.
Falconbridge Nickel Mines, Ltd. (12)
- Myers, Dr. James R.
Air Force Institute of Technology (121)
- Neuhaus, A.
Universität Bonn (66)
- Nicholson, A.
British Steel Corp. (95)
- Norris, L.F.
Sherritt Gordon Mines, Ltd. (18)
- Northwood, J.E.
National Gas Turbine Establishment (111)
- Oden, Dr. L.L.
Bureau of Mines (127)
- Ortega, M.R.
Celulosas De Heulva (86)

- Oudar, J.
Ecole Nationale Supérieure de Chimie de Paris (27)
(42)
- Packer, C.M.
Lockheed Missiles & Space Co. (146)
- Paidassi, J.
Centre d'Etudes Nucléaires de Saclay (21)
- Paton, Dr. Neil
North American Rockwell Corp. (157)
- Paul, W.
Orenda Limited (16)
- Peck, Dr. J.V.
TRW, Inc. (171)
- Perkins, R.A.
Lockheed Missiles & Space Co. (146)
- Pettit, Dr. F.S.
Pratt & Whitney Aircraft (164)
- Pfeiffer,
Hamburgische Elektrizitätswerke (54)
- Phelps, Dr. E.H.
U.S. Steel Corp. (173)
- Pichoir, R.
Office National d'Etudes et de Recherches (32)
- Pickering, Dr. Howard W.
U.S. Steel Corp. (174)
- Pollmann, S.
L.u.C. Steinmüller GmbH (57)
- Pourbaix, A.
Belgian Center for Corrosion Study, CEBELCOR (1)
- Pourbaix, M.
Belgian Center for Corrosion Study, CEBELCOR (1)
also Université Libre de Bruxelles
- Probst, Dr. H.B.
NASA-Lewis (152)
- Pryor, Dr. M.J.
Olin Corporation (160)
- Quintana, M.A.
Esso Petroleos Espanoles (88)
- Rahmel, Dr. A.
Dechema-Institut (50)
- Rapp, Prof. Robert A.
Ohio State University (159)
- Rentz, Warren A.
Ford Motor Company (136)
- Rhee, S.K.
Bendix Research Laboratories (126)
- Rhines, F.N.
University of Florida (135)
- Richards, E.G.
International Nickel Ltd. (104)
- Rickert, H.
Universität Dortmund (67)
- Rigaud, M.
Ecole Polytechnique (11)
- Rolls, R.
University of Manchester (108)
- Ross, T.K.
University of Manchester (107)
- Rossi,
Istituto Metalli Leggeri-Co.-Istituto Corrosioni (76)
- Roush, M.S.
AiResearch Mfg. Co. of Arizona (120)
- Roux.
Ecole des Mines (26)
- Roy, C.
University of Western Ontario (19)
- Sama, Lawrence
Sylvania Electric Products, Inc. (169)
- Schäferstein, H.
Kraftwerk Union AG (56)
- Schirmer, R.M.
Phillips Petroleum Company (163)
- Schluter, W.
Verein Deutscher Eisenhüttenleute e.V. (70)
- Scully, J.C.
University of Leeds (105)
- Schultz, Dr. J.W.
The International Nickel Co., Inc. (144)
- Schwenk,
Mannesmann-Forschungsinstitut (58)
- Seigle, Prof. L.
State University of New York (156)
- Sertour,
Société Nationale Industrielle Aérospatiale (34)
- Seybold, Dr. Alan U.
General Electric Co. (140)
- Sheasby, J.S.
University of Western Ontario (19)

- Schockley, Prof. G.
Pennsylvania State University (161)
- Simonetti, G.
Laboratorio Elettrico (77)
- Sims, Dr. Chester F.
General Electric Co. (137)
- Slama,
Ecole des Mines (261)
- Slodzian, G.
Office National d'Etudes et de Recherches (32)
- Smeltzer, Prof. W.W.
McMaster University (13)
- Smart, R.A.
International Nickel Ltd. (104)
- Spach, Dr. H.S.
General Electric Co. (140)
- Spinedi, Prof. Paolo
Università di Bologna (79)
- Steele, Dr. Warren C.
Avco Corp. (122)
- Steller,
Vereinigte Kesselwerke AG (72)
- Stetson, A.R.
Solar Division (166)
- Strassburger, Ch.
August Thyssen-Hütte AG (45)
- Stringer, Prof. John
University of Liverpool (106)
- Sturla, P.
ENIE Nazionale Per l'Energia Elettrica (75)
- Svedberg, Dr. R.C.
Westinghouse Electric Corp. (177)
- Swisher, Dr. J.H.
Bell Telephone Laboratories (125)
- Syre,
Iremetaux, G.P. (36)
- Taelmans, G.
Laboratoire Belge de l'Industrie Electrique (7)
- Lillian, Dr. N.M.
Aerospace Research Laboratories (119)
- Tedmon, Dr. C.S. (Jr.)
General Electric Co. (140)
- Telang, Yesh P.
Ford Motor Company (136)
- Tietz, Dr. E.E.
Lockheed Missiles & Space Co. (146)
- Toft, I.H.
Midlands Region, C.E.G.B. (110)
- Trenouth, J.M.
National Research Council of Canada (15)
- Tripp, Dr. W.C.
Systems Research Laboratories, Inc. (170)
- Truman, J.F.
Brown-Firth (96)
- Iseung, A.C.C.
The City University (98)
- Fylecote, R.F.
University of Newcastle-Upon-Tyne (113)
- Umland, F.
Forschungsvereinigung Verbrennungskraftmaschinen (53)
- Umland, F.
Universität Münster (69)
- Uhlig, Prof. Herbert H.
Massachusetts Institute of Technology (149)
- Uzan,
Université de Lyon (38)
- Valensi, G.
Université de Poitiers (43)
- Van der Poorten, Prof. H.
Faculté Polytechnique (3)
- Vanleuvenhaghe, Claude
Université Catholique de Louvain (5)
- van Muylaer, G.
Belgian Center for Corrosion Study, CEBELCOR (1)
- van Staa, H.
Laboratory for Thermal Power Engineering (81)
- Van Vlack, Prof. Lawrence H.
University of Michigan
- Verge, C.
SNAM Progetti (78)
- Vernik, E.D.
University of Florida (135)
- Vigne,
Université de Nancy (40)
- Wagner, Prof. Carl
Max-Planck-Institut für Physikalische Chemie (60)
- Wagner, Prof. J. Bruce (Jr.)
North Western University (158)

- Wallace, Dr. W.
National Research Council of Canada (15)
- Wasilewski, Gerald
General Electric Company (137)
- Weaver, M.J.
National Gas Turbine Establishment (111)
- Wesseling, W.
Stahlwerke Südwestfalen AG (62)
- Wheatfall, Walter L. (Sr.)
Naval Ship Research and Development Laboratory (155)
- Whelan, Dr. E.P.
National Research Council of Canada (15)
- Wickert, K.
Berliner Kraft und Licht-AG (48)
- Wilcox, Dr. B.A.
Battelle Columbus Laboratories (124)
- Wilson, John R.
Queen's University (17)
- Wilson, R.W.
Shell Research Ltd. (118)
- Winterbottom, A.B.
Norges Tekniske Høgskole (84)
- Wlodek, Dr. S.T.
Cabot Corporation (128)
- Wolf, Dr. James S.
Clemson University (129)
- Wolsin, Dr. Sam
Curtiss-Wright Corp. (131)
- Wood, Dr. G.C.
University of Manchester (107)
- Worrell, Prof. W.L.
University of Pennsylvania (162)
- Wukusick, C.S.
General Electric Company (141)
- Yamamoto, Dr. Albert S.
University of Denver (134)